INSAR APPLICATIONS
For Highway Transportation Projects

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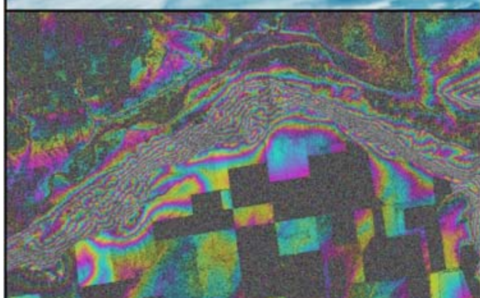

U.S. Department of Transportation
Federal Highway Administration

CTIP

Federal Lands Highway
Commitment to Excellence

Central Federal Lands Highway Division
12300 West Dakota Avenue
Lakewood, CO 80228

FOREWORD

The Federal Lands Highway (FLH) of the Federal Highway Administration (FHWA) promotes development and deployment of applied research and technology applicable to solving transportation related issues on Federal Lands. The FLH provides technology delivery, innovative solutions, recommended best practices, and related information and knowledge sharing to Federal agencies, Tribal governments, and other offices within the FHWA.

Interferometric Synthetic Aperture Radar (InSAR) technology provides the ability to detect ground movement from satellites. Wherever vertical differential movement occurs due to subsidence, slides, settling, or creep, InSAR can estimate the differential movement to sub-centimeter resolution. Several radar satellites are commercially available to collect InSAR data on corridors of interest. For some locations, historical data dating back to 1992 is also available.

The FHWA is interested in evaluating this technology to monitor slide movements that may impact roads. To this end, the pilot project described herein was undertaken to evaluate InSAR technology at three sites using historical and recently acquired satellite data. This is the final report for this project, which establishes the relative effectiveness of InSAR in monitoring ground movement, and includes a comparison to conventional survey techniques. In addition, the described guidelines for the coordinated use of InSAR with other FHWA data collections, including photogrammetry, field surveys, boreholes and slope inclinometers.

James W. Keeley, P.E., Director of Project Delivery
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Technical Report Documentation Page

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16. Abstract
Satellite Synthetic aperture radar (SAR) technology, in combination with interferometry (InSAR), has the ability to measure topography or ground movement to sub-centimeter accuracy. Many factors affect the ability to apply InSAR for the detection of slope movement. If these factors are considered, InSAR can often be successfully used to monitor slope movement. The Federal Lands Highway Program (FLH) of the Federal Highway Administration (FHWA) has initiated the project described within this report to evaluate the utility of InSAR technology to monitor slide movements that impact road networks. The project objective was to establish and demonstrate reliable, cost effective procedures to measure ground movement using InSAR in support of federal highways projects. This report describes the effectiveness of InSAR in monitoring ground movement, and recommends guidelines for the coordinated use of InSAR with other FLH data collections, including photogrammetry, field surveys, boreholes and slope inclinometers. InSAR has the unique ability to measure both present and prior (based on the data archives accumulated over the last 12 years) ground movement and consequently, the present study involved collection and analysis of InSAR data from both the past and present at three sites. The first site, the Prosser slide in Benton County WA, provided a site with excellent InSAR coherence and gradual creeping movement that demonstrated the limits of InSAR movement measurement. The combination of a set of InSAR movement maps over a two-year period produced movement on the order of several centimeters that qualitatively correlated well with site observations and slope inclinometer measurements. The second slope, the Cimarron slide in Owl Creek CO, exhibited moderate coherence and highly visible InSAR movement signatures were produced over periods of only several months. The third site, in Mesa Verde National Park near Cortez, CO, is a region of significant topographic relief, which made the use of satellite-based InSAR a challenge.

17. Key Words **SAR, INSAR, DINSAR, GROUND MOVEMENT, SUBSIDENCE, SLOPE STABILITY**		18. Distribution Statement No restriction. This document is available to the public from the sponsoring agency at the website http://www.cflhd.gov.	
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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	Millimeters	mm
ft	feet	0.305	Meters	m
yd	yards	0.914	Meters	m
mi	miles	1.61	Kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	Hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	Milliliters	mL
gal	gallons	3.785	Liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz	ounces	28.35	Grams	g
lb	pounds	0.454	Kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	Lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	Newtons	N
lbf/in^2	poundforce per square inch	6.89	Kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	Inches	in
m	meters	3.28	Feet	ft
m	meters	1.09	Yards	yd
km	kilometers	0.621	Miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	Acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	Gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	Ounces	oz
kg	kilograms	2.202	Pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	Poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. Appropriate rounding should be made to comply with Section 4 of ASTM E380.
(Revised March 2003)

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LIST OF ABBREVIATIONS AND SYMBOLS

ALOS	- Advanced Land Observing Satellite
DEM	- Digital Elevation Model
DInSAR	- Differential Interferometric Synthetic Aperture Radar
DTED	- Digital Terrain Elevation Data
EROS	- Earth Remote Observation Satellite
ERS	- European Remote-Sensing Satellite
FHWA	- Federal Highway Administration
FLH	- Federal Lands Highways
GCPs	- Ground Control Points
GIS	- Geographic Information System
GPS	- Global Positioning System
InSAR	- Interferometric Synthetic Aperture Radar
IPTA	- Interferometric Point Target Analysis
JERS	- Japanese Earth Resources Satellite
LIDAR	- Light Detection and Ranging
MP	- Milepost
NAD	- North American Datum
NMAS	- National Map Accuracy Standards
PALSAR	- Pulsed Array type L-band SAR
PS	- Point Scatterer
PS InSAR	- Point Scatterer InSAR
SAR	- Synthetic Aperture Radar
SI	- Slope Inclinometer
SRTM	- Shuttle Radar Topography Mission
USGS	- United States Geological Survey
UTM	- Universal Transverse Mercator
WGS	- World Geodetic System
WS-DOT	- Washington State Department of Transportation